

| Report Documentation Page  |                                    |                                     |   | Form Approved<br>OMB No. 0704-0188                  |                                 |
|--|------------------------------------|-------------------------------------|---|---|---------------------------------|
| Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. |                                    |                                     |   |   |                                 |
| 1. REPORT DATE<br><b>JUL 2013</b>  |                                    | 2. REPORT TYPE                      |   | 3. DATES COVERED<br><b>00-00-2013 to 00-00-2013</b> |                                 |
| 4. TITLE AND SUBTITLE<br><b>A L-Band Superstrate Lens Enhanced Antenna and Array for Tactical Operations</b>   |                                    |                                     |   | 5a. CONTRACT NUMBER                                 |                                 |
|  |                                    |                                     |   | 5b. GRANT NUMBER                                    |                                 |
|  |                                    |                                     |   | 5c. PROGRAM ELEMENT NUMBER                          |                                 |
| 6. AUTHOR(S)   |                                    |                                     |   | 5d. PROJECT NUMBER                                  |                                 |
|  |                                    |                                     |   | 5e. TASK NUMBER                                     |                                 |
|  |                                    |                                     |   | 5f. WORK UNIT NUMBER                                |                                 |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)<br><b>Space and Naval Warfare Systems Center Pacific,Advanced Integrated Circuits Technology,53560 Hull St,San Diego,CA,92152-5001</b>  |                                    |                                     |   | 8. PERFORMING ORGANIZATION REPORT NUMBER            |                                 |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)  |                                    |                                     |   | 10. SPONSOR/MONITOR'S ACRONYM(S)                    |                                 |
|  |                                    |                                     |   | 11. SPONSOR/MONITOR'S REPORT NUMBER(S)              |                                 |
| 12. DISTRIBUTION/AVAILABILITY STATEMENT<br><b>Approved for public release; distribution unlimited</b>  |                                    |                                     |   |   |                                 |
| 13. SUPPLEMENTARY NOTES  |                                    |                                     |   |   |                                 |
| 14. ABSTRACT<br><b>The design of a 1.2 GHz microstrip antenna utilizing a superstrate layer for gain enhancement is presented. An 4 x 1 antenna array is also studied with the effects of various inter-elemental spacings investigated. The single antenna element achieves 5.74 dB of gain enhancement in simulation through the use of the superstrate lens. The 4 x 1 superstrate array achieves approximately 2.5 dB of gain enhancement in simulation.</b>   |                                    |                                     |   |   |                                 |
| 15. SUBJECT TERMS  |                                    |                                     |   |   |                                 |
| 16. SECURITY CLASSIFICATION OF:  |                                    |                                     | 17. LIMITATION OF ABSTRACT<br><b>Same as Report (SAR)</b> | 18. NUMBER OF PAGES<br><b>2</b>                     | 19a. NAME OF RESPONSIBLE PERSON |
| a. REPORT<br><b>unclassified</b>   | b. ABSTRACT<br><b>unclassified</b> | c. THIS PAGE<br><b>unclassified</b> |   |   |                                 |

# A L-Band Superstrate Lens Enhanced Antenna and Array for Tactical Operations

Jia-Chi Samuel Chieh<sup>1</sup>, Chris Meagher<sup>2</sup>, David Hooper<sup>3</sup>

Spawar Systems Center Pacific

<sup>1</sup>Advanced Integrated Circuits Technology <sup>2</sup>Tactical Edge Wireless Networks <sup>3</sup>Unmanned Systems  
San Diego, CA, 92152-5001  
sam.chieh@navy.mil

**Abstract**—The design of a 1.2 GHz microstrip antenna utilizing a superstrate layer for gain enhancement is presented. An 4 x 1 antenna array is also studied with the effects of various inter-elemental spacings investigated. The single antenna element achieves 5.74 dB of gain enhancement in simulation through the use of the superstrate lens. The 4 x 1 superstrate array achieves approximately 2.5 dB of gain enhancement in simulation.

## I. INTRODUCTION

Directional communications in the L-Band (1 - 2 GHz) can be challenging. Directionality is proportional to aperture size, and in the L-Band, often times space/area limitations (xy-plane) determine the maximum directionality that can be realized. The microstrip patch antenna is a widely used antenna in this regime as it is light weight and is easily scalable for increased gains.

It has been demonstrated that in addition to increasing the aperture size in the xy-dimension in order to increase the gain, a superstrate dielectric lens can be used in the z-dimension in order to boost the gain. This method was first introduced in [1] and has subsequently been demonstrated in various configurations. In [2] operation is demonstrated in the X-band and in [3] extended to demonstrate a 4 x 2 array. In [3] the frequency of operation is increased to the millimeter-wave frequency regime at around 60 GHz.

In this paper, we demonstrate an aperture coupled stacked patch antenna and array with gain enhancement through the use of a spaced dielectric superstrate lens.

## II. DESIGN

### A. Single Antenna with Superstrate

In order to obtain a wider bandwidth, an aperture coupled stacked patch antenna topology was adopted. Figure 1 shows the side profile of the printed circuit board stackup. The dimension of the driven patch is 80 mm x 80 mm. The dimension of the parasitic patch is 70 mm x 70 mm. Under the resonance conditions for high gain the thickness of the superstrate should be approximately  $\lambda_g/4$ . In addition the height of the superstrate lens should be separated from the ground plane by a distance of  $\lambda/2$ . This was used as a baseline starting point, for which optimization routines were used in HFSS to fine tune those parameters. The size of the superstrate lens was 420 mm x 420 mm.

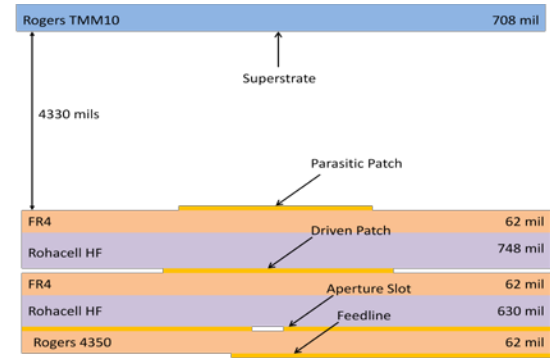


Figure 1. Side cross-section and stackup for superstrate aperture coupled stacked patch antenna

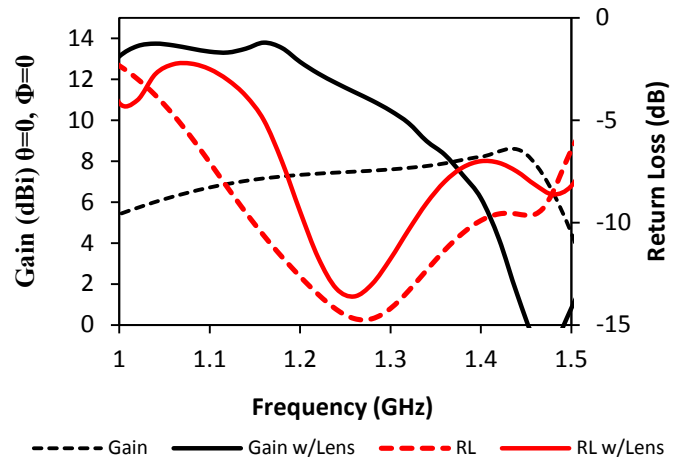


Figure 2. Simulated Gain and Return Loss with and without the superstrate lens

As can be seen in Figure 2, without the lens the single antenna has a 1.9:1 VSWR bandwidth of 19% with a gain of 7.11 dBi at 1.2 GHz. When the superstrate lens is added, the VSWR bandwidth reduces to 9.5%, however the gain at 1.2 GHz increases to 12.85 dBi, an improvement of 5.74 dB. Finally Figure 3 shows the simulated radiation patterns at 1.2 GHz in the *E*-Plane.

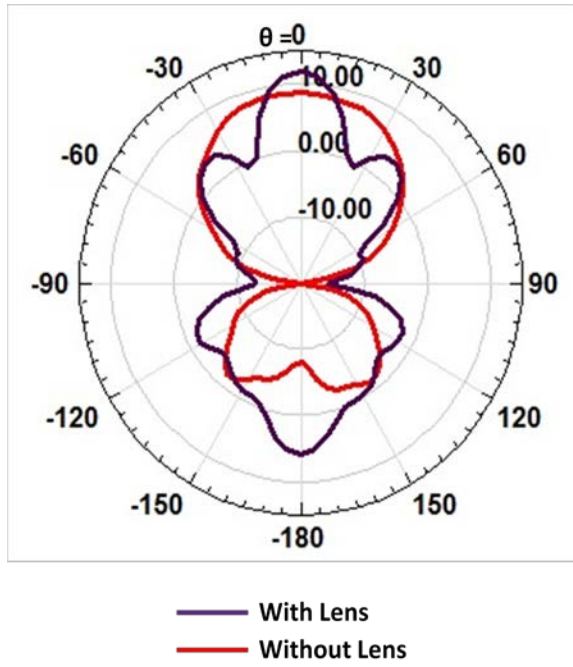


Figure 3. Simulated radiation pattern at 1.2 GHz with and without the superstrate lens in the  $E$ -plane

#### B. $4 \times 1$ Array

The simplest way to increase gain for microstrip type antennas is to configure them into an array. When in an array configuration, effects such as mutual coupling and ground plane shadowing can adversely affect the performance when a superstrate lens is used. In order to understand the effects, we simulated two cases. The first in which the antenna elements are spaced  $1\lambda$  apart, and another in which the inter-elemental spacing is  $\lambda/2$ . In all cases, a T-Junction corporate feed network is used.

Figure 4 shows the simulated return loss and gain of the  $4 \times 1$  array with and without the superstrate lens. It becomes apparent that when the array is spaced closely,  $\lambda_0/2$ , then the benefits of the superstrate is absent, and the gain is actually degraded as compared without the superstrate. This is primarily attributed to mutual coupling and ground plane shadowing effects [5]. However, when the inter-elemental spacing increases to  $1\lambda$ , performance enhancement is observed. The total size of the  $1\lambda$  array is 420 mm x 1070 mm.

The true benefits of the superstrate are seen at below 1.2 GHz. The main reason is attributed to the spacing of the superstrate and the ground plane. From 1.1 – 1.2 GHz, the gain is enhanced by approximately 2.5 dB. It is however, acknowledged that the matching efficiency is low in this regime. This can be remedied by tuning either the antenna or superstrate. It is apparent that the gain bandwidth becomes narrowband with the superstrate lens.

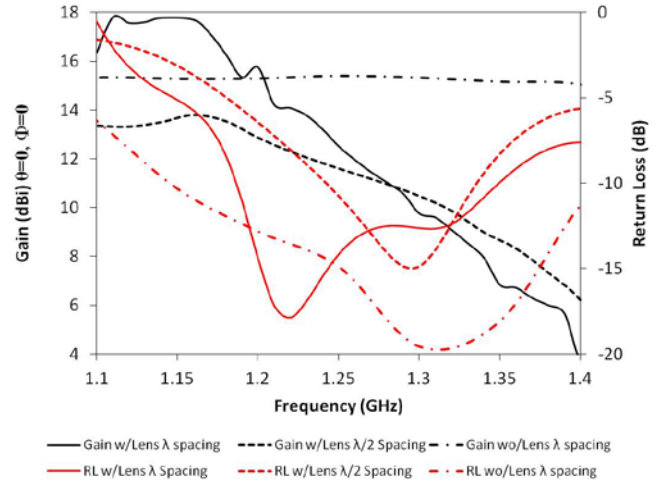


Figure 4. Simulated Gain and Return Loss of the  $4 \times 1$  array with and without the superstrate lens

### III. CONCLUSION

We present the design of an aperture coupled stacked patch antenna and array with a gain enhancing superstrate lens. Such an antenna can be used to improve the gain without sacrificing area in the  $xy$ -plane. For the single antenna, 5.74 dB of gain improvement is observed with a 9.5% reduction in the VSWR bandwidth. For the  $4 \times 1$  array, 2.5 dB of gain improvement was observed, however with a minimized gain bandwidth.

### REFERENCES

- [1] Jackson, D.; Alexopoulos, N.; , "Gain enhancement methods for printed circuit antennas," *Antennas and Propagation, IEEE Transactions on* , vol.33, no.9, pp. 976- 987, Sep 1985
- [2] Shen, X.-H.; Delmotte, P.; Vandenbosch, G.A.E.; , "Effect of superstrate on radiated field of probe fed microstrip patch antenna," *Microwaves, Antennas and Propagation, IEE Proceedings* , vol.148, no.3, pp.141-146, Jun 2001
- [3] Wonkyu Choi; CheolSig Pyo; Cho, Y.H.; Jaelck Choi; Jongsuk Chae; , "High gain and broadband microstrip patch antenna using a superstrate layer," *Antennas and Propagation Society International Symposium, 2003. IEEE* , vol.2, no., pp. 292- 295 vol.2, 22-27 June 2003
- [4] Vettikalladi, H.; Le Coq, L.; Lafond, O.; himdi, M.; , "Wideband and high efficient aperture antenna with superstrate for 60 GHz indoor communication systems," *Antennas and Propagation Society International Symposium (APSURSI), 2010 IEEE* , vol., no., pp.1-4, 11-17 July 2010
- [5] C. Meagher, "Investigations on Wideband Aperture-Coupled Microstrip Patch Antennas and Arrays Employing Spaced Dielectric Covers for Enhanced Gain Performance," Master Thesis, Dept. Electrical and Computer Systems Engineering, San Diego State University, San Diego, USA, 2009.